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PULSATIONS OF AURORA GLOW AND IRREGULAR SPP OF THE GEOMAGNETIC FIELD

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SUMMARY

The dynamo-theory of irregular SPP-s of the geomagnetic field occurring during polar bay-like disturbances is discussed in this paper. A formula is proposed, which links the SPP amplitudes with the pulsations of aurora glow.

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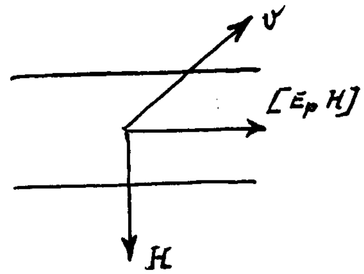
The works [1 — 5] bring forth the facts pointing to the close relationship between the pulsations of polar aurora and the SPP-s of the geomagnetic field of the type sip and pc^{o}. Thus, during polar bay-like disturbances and universal magnetic storms, the greater part of pulsation peaks of aurora glow are attended by peaks of irregular SPP-s of the geomagnetic field. Moreover, both the pulsations and the SPP-s have identical spectra and a tendency is noted to SPP amplitude increase with the rise of the amplitude of pulsations, and so forth.



Such a close link of both events allows the assumption that the aurora glow and type-sip and -pc^{o} pulsations constitute different manifestations of the same event — the intrusion of plasma flux in the aurora zone of the upper atmosphere. This intrusion induces the appearance of aurorae and of the region of increased ionization in the 100 — 200 km altitude range.

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* PUL'SATSII SVECHENIYA POLYARNYKH SIYANIY I IRREGULYARNYYE KPK GEOMAGNITNOGO POLYA

It is well known from observations [6] that the region of increased ionization in the aurora zone may have dimensions in longitude from 20 to 400 km and from 1000 to 5000 in latitude. Consequently, in the first approximation the region of increased ionization may be represented by an infinite band, in which the ionization density is significantly greater than that of the surrounding ionosphere, that is $N \gg N_0$. At the same time, the magnetic field is directed downward along the axis **z** and the velocity vector of the ionospheric wind is perpendicular to the boundaries of the irregularity (see figure of the preceding page). It was shown in the works [7 — 10] that the plasma flux intruding the upper atmosphere fluctuates. The magnitude of fluctuations with periods to 10 sec. constitutes 1 — 10% of the total flux intensity. The fluctuations of the primary flux induce pulsations of aurora glow. The primary particles, electrons and ions, passing through the rarefied gas of the upper atmosphere, induce a simultaneous emergence of excited and ionized particles. At the same time the rate of ion formation and the intensity of glow are linked in the first approximation by a correlation of the form

$$q = \frac{\sigma_i}{\sigma_\lambda} \delta I.$$

where σ_i is the effective ion formation cross section; σ_λ is the effective cross section of emission de-excitation with wavelength λ; q is the rate of ion formation; δI is the glow intensity of the emission excited by primary electrons.

The ionization balance equation is written in the form

$$\frac{dN}{dt} = q - \alpha N^2, \tag{2}$$

where N is the density of ionization; α is the recombination coefficient. In case of irregular short-period oscillations the rate of ion formation may be represented with a sufficient precision by a sequence of triangular pulses, with the possibility for everyone of them to be represented by the following function :

$$\begin{aligned} q(t) &= 0, & t &< t_0, \\ q(t) &= kt, & t_0 &< t < T/2, \\ q(t) &= k(T-t), & T/2 &< t < T. \end{aligned} \tag{3}$$

At consideration of SPP the period of action of the ion-forming function may be taken sufficiently small for the number of particles, having recombined during the action time of the pulse to be neglected, that is, to estimate that $q \gg {}^1\!/_2\, \alpha N T q$. At $\alpha \sim 10^{-8} - 10^{-9}$ this admission will be valid for SPP-s with period from 1 to 100 sec. Consequently, if the function is represented in the form (3), the solution of the equation will have the form

$$\delta N_m = q_m (T/2), \qquad (4)$$

where δN_m is the maximum density of ionization; q_m is the maximum rate of ion formation; T is the action period of the ion-forming function. The equation (4) may be written in another form, substituting in place of ion formation rate its expression through the intensity of glow. Then

$$\delta N_m = \frac{\sigma_i}{\sigma_\lambda} \frac{T}{2} \delta I. \qquad (5)$$

The equation (5) is valid in the case when the emission glow excitation is triggered by the same particles as the ionization. According to the opinion of most of the researchers, such emission is that of the line 3914 Å [11]. In case of uniform ionosphere the flow of a partly ionized gas of the ionosphere in the magnetic field of the Earth leads to the existence in the system of coordinates, linked with moving gas particles, of an induced electric field [12 – 14]. If we estimate that the vector of the geomagnetic field is directed vertically downward, the value of the field is

$$E = \frac{1}{c} [vH].$$

The electric field induces electron and ion currents

$$j_e = N\sigma_1{}^e E - N\sigma_2{}^e \frac{[EH]}{H}, \quad j_i = N\sigma_1{}^i E + N\sigma_2{}^i \frac{[EH]}{H}, \qquad (6)$$

where $\sigma_1{}^{e,i}$, $\sigma_2{}^{e,i}$ are respectively the electron and ion conductance along and across the magnetic field. The currents are induced by particle motion with a velocity u parallelwise and perpendicularly to E. The motion velocity, parallelwise to E, is determined by the equality

$$N\sigma_1{}^{e,i} E = N_e u_{\|}{}^{e,i}. \qquad (7)$$

Consequently,

$$u^{\|e, i} = \frac{N\sigma_1^{e, i} E}{N_e} = \frac{\nu\omega}{\nu^2 + \omega^2} \cdot v. \tag{8}$$

The flow velocity of particles perpendicularly to E is analogously determined as follows

$$u_\perp^{e, i} = \frac{-\omega^2}{\nu^2 + \omega^2} v.$$

According to data of [6], at heights from 100 to 200 km, that is at the level of the E-layer

$$\omega_e^2 / (\nu_e^2 + \omega_e^2) \approx 1, \ \omega_i^2 / (\nu_i^2 + \omega_i^2) \ll 1 \tag{9}$$

and

$$\nu\omega / (\nu^2 + \omega^2) \ll 1$$

for ions as well as for electrons. Consequently

$$u_\|^{e, i} \ll v, \quad u_\perp^i \ll v, \quad u_\perp^i \approx -v, \tag{10}$$

that is, the electrons are fixed in the ionosphere relative to observer on Earth, while the ions move with the gas. Therefore, the motion of particles in the ionosphere in the 100 – 200 km altitude range leads to the partition of charges. In case of the existence of irregularity in the ionosphere, similar to the one described above, this charge partition will lead to the accumulation of charges on the walls of the irregularity if the motion of particles has a velocity component perpendicular to these walls. The field induced by these charges lowers the Hall current. The magnitude of the polarization field is determined from the equality of the normal current density components at irregularity boundary [13, 14], that is,

$$j_n = -N_0\sigma_2 \frac{[EH]}{H} = N\sigma_1 E_p - N\sigma_2 \frac{[EH]}{H}, \tag{11}$$

whence

$$E_p = \frac{N - N_0}{N} \frac{\sigma_2}{\sigma_1} \frac{[EH]}{H}. \tag{12}$$

The field E_p compensates the Hall current across the zone and, at the same time, induces the Hall current's increase along the zone of increased conductance, making the Hall current equal to

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$$j_H = -N\sigma_2\frac{[E_pH]}{H} = -(N-N_0)\frac{\sigma_2^2}{\sigma_1}\frac{[[EH]H]}{H^2}. \qquad (13)$$

The total current along the irregularity is

$$j = N\left(\sigma_1 + \frac{N-N_0}{N}\frac{\sigma_2^2}{\sigma_1}\right)E. \qquad (14)$$

In case of magnetic storms or bay-line disturbances in the aurora zone, the ionization density in the zone is significantly greater than that in the surrounding ionosphere. That is why the current density is

$$j \approx N(\sigma_1^2 + \sigma_2^2/\sigma_1)E. \qquad (15)$$

During SPP the aurora glow intensity, and thus also the rate of ion formation, fluctuate continuously. Consequently, the ionization density in the ionosphere fluctuates also. When discussing the SPP-s of the geomagnetic field of the types sip and pc°, that is the oscillations with periods from 1 to 100 sec., the long-period variations of ionization density may be represented as a quasistationary process. Therefore, the ionization density may be written in the form of a sum

$$N = N_1 + \delta N(t). \qquad (16)$$

The relative variation of current density is determined as

$$\frac{\Delta j}{j} = \frac{\Delta N}{N} + \frac{\Delta\sigma}{\sigma} + \frac{\Delta v}{v} + \frac{\Delta H}{H}, \qquad (17)$$

that is, the variations of ionosphere current density is proportional to the variation of ionization density. The variation of the ionization density in the ionosphere in case of SPP is determined by the formula (5). Consequently, the density variation of the dynamocurrent in the ionosphere for the case of type-sip and pc° SPP's, developing at time of bay-like disturbance, is determined by the formula

$$\frac{\sigma_i}{\sigma_\lambda}\frac{T}{2}\left(\sigma_1 + \frac{N-N_0}{N}\frac{\sigma_2^2}{\sigma_1}\right)\frac{[vH]}{c}\delta I. \qquad (18)$$

The variation of the geomagnetic field, induced by this current, may be determined by the formula

$$\delta H = \int_v \frac{[\delta j R]}{R^3}dv. \qquad (19)$$

The amplitude of geomagnetic field's type-sip and pc^0 SPP's may be computed from the following initial data: the periods of SPP's lay in the limits from 1 to 100 sec, the intensity of aurora light flux pulsations constitutes 1 — 10% of the total aurora intensity and is equal to some 0.1 — 1 k-rayleighs. The ratio $\sigma_i / \sigma_\lambda = 50$, the value of conductance is $\sigma_\lambda = (1 - 4) \cdot 10^{-19}$ CGSM. The velocity of the ionospheric wind is $v = 100$ m/sec, $H = 0.5$ oe. The ionosphere current may be approximated by a flat layer. In this case the amplitude of irregular type- sip and pc^0 SPP's induced by the fluctuations of the ionospheric dynamocurrent, will be equal to 0.1 — 20 γ. Similar amplitudes of irregular SPP's are more often observed in the aurora zone during bay-like disturbances. It follows from (18) that the glow pulsations, emerging in the absence of magnetoionospheric disturbances, can not lead to the appearance in the geomagnetic field of significant SPP's.

**** THE END ****

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